### 880. *Seminar in the Philosophy of Science*

*Fall, Winter. 4(3-0) May re-enroll for a maximum of 12 credits. Approval of department.*

### 890. *Graduate Reading Course*

*Fall, Winter, Spring, Summer. 1 to 10 credits. May re-enroll for credit. Approval of department.*

Supervised reading course for advanced graduate students for more thorough investigation of special fields.

### 899. *Research*

*Fall, Winter, Spring, Summer. Variable credit. Approval of department.*

### 999. *Research*

*Fall, Winter, Spring, Summer. Variable credit. Approval of department.*

## PHYSICAL SCIENCE PHS

## College of Natural Science

The content of courses 400, 405, 410 and 412, as well as the problems course, 890, may vary from term to term. Brochures giving detailed information about individual courses are available in the Science and Mathematics Teaching Center and the Office of the Assistant Dean for Lifelong Education. These courses are primarily designed for in-service teachers and interested adults and are offered in off-campus locations.

### 203. *Foundations of Physical Sciences*

*Fall, Winter, Spring, Summer. 4(3-3) Primarily for elementary school teachers.*

Integrated descriptive course in the elements of physical science including the interrelations among chemistry, geology, meteorology, astronomy, and physics.

### 400. *Physical Science for Teachers*

*Fall, Winter, Spring, Summer. 3 or 4 credits. May re-enroll for a maximum of 12 credits. Teacher certification with science major or minor.*

For in-service teachers stressing process, inquiry, meaning and field experience. Topics will be generated from the classroom experiences of participants.

### 405. *Topics in Physical Science*

*Fall, Winter, Spring, Summer. 1 to 3 credits. May re-enroll for a maximum of 6 credits if different topic is taken. Approval of department.*

Presentation of single topics from the physical sciences by senior faculty and guest lecturers. Topics are selected to facilitate development of strong physical science programs in schools.

### 410. *Seminar on Recent Advances in Physical Science*

*Fall, Winter, Spring, Summer. 1 to 3 credits. May re-enroll for a maximum of 6 credits if different topic is taken. Approval of department.*

A series of lectures by senior faculty of topics on the history, development, the most recent advances and the possible future and limits of the physical sciences.

### 412. *Recent Advances in Earth Science*

*Fall, Winter, Spring, Summer. 1 to 3 credits. May re-enroll for a maximum of 6 credits if different topic is taken. Approval of department.*

A series of lectures by senior faculty on the history, development, most recent advances and possible future trends in the earth sciences.

### 430. *Planetarium and Classroom Instruction*

*Summer. 4(3-2) AST 119 or 217 or 229.*

Practical operation, techniques, and methods of instruction for astronomy and other sciences in the planetarium theater and the classroom.

### 431. *Problems in Planetarium Education*

*Fall, Winter, Spring, Summer. 1 to 3 credits. May re-enroll for a maximum of 6 credits. Approval of department.*

Individual study, training, or project under the direction of a faculty member. Often the training will be in the area of actual delivery of planetarium presentations.

### 890. *Problems in Physical Science*

*Fall, Winter, Spring, Summer. 1 to 12 credits. May re-enroll for a maximum of 15 credits. Bachelors degree in a physical science.*

## PHYSICAL SYSTEMS IN AGRICULTURE AND NATURAL RESOURCES

*See* Agricultural Engineering

## PHYSICS PHY

## College of Natural Science

Introductory physics courses are offered in both the lecture-recitation and the Competency-Based-Instructional (CBI) format. In the latter format the students are carefully guided through each course via written materials with ample consulting time available. Both content and pace of course are flexible to suit student's needs and interests, final grades being based on total amount of material for which student's mastery is certified. The introductory courses may be grouped by the application of two criteria: the interests of the students the courses are designed to serve and the method of instruction employed.

*Lecture-Recitation format*

237, 238, 239, three credits each, designed primarily for students with interest in the life and earth sciences. The mathematics prerequisite is credit for or concurrent enrollment in college algebra and trigonometry (MTH 109 or 111).

287, 288, 289, four credits each, designed primarily for students with interest in the physical sciences, mathematics and engineering. The mathematics prerequisite is credit for or concurrent enrollment in calculus III with vectors (MTH 214).

291, 292, 293, four credits each, designed primarily for Physics majors and others with a special interest in Physics. The mathematics prerequisite is credit for or concurrent enrollment in calculus III with vectors (MTH 214), the Honors section recommended.

*Competency Based Instructional Format*

237B, an alternate way to earn credit in 237.

281, 282, 283, three credits each, designed for students with interest in the natural sciences, including the life and earth sciences. The mathematics prerequisite is calculus I with analytic geometry (MTH 112).

287A, 288A, 289A, one credit each, to combine with 281, 282, 283 to give a four credit per term introductory series.

291A, 292A, 293A, one credit each, to combine with 281, 287A; 282, 288A; 283, 289A or 287, 288, 289 to give a five credit introductory series.

291B, 292B, 293B (Honors Physics) in which the five credit introductory series is covered in one term for each course.

The courses taught via the two formats may be grouped to give a wide variety of introductory physics courses. The following equivalencies exist:

237, 238, 239 may be taken as 237B, 238, 239.

287, 288, 289 may be taken as 281, 287A; 282, 288A; 283, 289A.

291B, 292B, 293B may be taken as 281, 287A, 291A; 282, 288A, 292A; 283, 289A, 293A; or as 287, 291A; 288, 292A; 289, 293A.

A student may change from one group of introductory courses to another, but may not earn credit for more than one complete sequence.

Credit may not be earned for more than one of the courses 294, 357, or 364.

201, 301, 357, 430, and 431 cannot be used to meet the requirements for a major in Physics.

Prerequisites to nearly all the first courses in the 300-400 level course sequences are stated in terms of the Introductory Physics courses. The course selected for prerequisite is that which requires the least number of credits and the least mathematical background the department considers adequate. The corresponding term of any introductory sequence that requires a mathematical background equal to or greater than that of the stated prerequisite may be substituted for the stated prerequisite.

All 400 level physics courses (except 430 and 431) require 289 or 293.

### 201. *The Science of Sound I: Rock, Bach and Oscillators*

*Winter. 3(3-0) or 4(4-0) Interdepartmental with the Department of Mechanical Engineering.*

Man-sound relationship. Production, propagation, detection of sounds. Voice, hearing, scales, timbre, musical instruments. Room acoustics. Electronic reproduction and synthesis of music. Demonstrations emphasized.

### 202. *The Science of Sound II*

*Spring. 3(3-0) or 4(4-0) 201. Interdepartmental with and administered by the Department of Mechanical Engineering.*

Nature, generation, and propagation of sound. Acoustical phenomenon and measurements. Storage and manipulation of sound in numerical form. Music programming.

### 203. *Science of Light and Color for Nonscientists*

*Spring. 4(4-0)*

Properties of light with applications to mirrors, lenses, eyes, cameras, lasers, holography. Light spectra, color TV, color vision, filters, pigments. Black and white and color photography.

### 237. *Introductory Physics*

*Fall, Winter. 3(4-0) MTH 102 or 109 or 111 or concurrently.*

Mechanics, including Newton's Law, momentum, energy, and conservation laws.

### 237B. *Introductory Physics I*

*Fall, Winter, Spring. 3 credits. CBI only. MTH 102 or 109 or 111 or concurrently.*

Mechanics including Newton's Law, momentum, energy, and conservation laws.

### 238. *Introductory Physics*

*Winter, Spring. 3(4-0) 237.*

Heat, electricity and magnetism.

### 239. *Introductory Physics*

*Fall, Spring. 3(4-0) 238.*

Wave motion, sound, light, and modern developments.

### IDC. *Energy Consumption and Environmental Quality*

*For course description, see* Interdisciplinary Courses.

### 257. *Introductory Physics Laboratory*

*Fall, Winter, Summer. 1(0-2) 237 or 281, or concurrently.*

Mechanics and heat.

### 258. *Introductory Physics Laboratory*

*Winter, Spring, Summer. 1(0-2) 238 or 282 or concurrently.*

Heat, electricity and magnetism.

### 259. *Introductory Physics Laboratory*

*Fall, Spring, Summer. 1(0-2) 239 or 283 or concurrently.*

Wave motion, sound, light and modern developments.

### 281. *Basic Physics I*

*Fall, Winter, Spring. 3 credits—CBI only. MTH 112.*

Static equilibrium, Newton's laws, power, harmonic motion, rotational motion.

### 282. *Basic Physics II*

*Fall, Winter, Spring. 3 credits—CBI only. 281.*

Microscopic origin of heat flow and first law of thermodynamics, electric and magnetic forces and sources, direct currents.

### 283. *Basic Physics III*

*Fall, Winter, Spring. 3 credits—CBI only. 282.*

Physics of sound, light, and optical instruments, wave-particle duality, radioactivity, fission and fusion, elementary particles, fundamental forces of nature.

### 284. *Calculus Concepts in Physics I*

*Fall, Winter, Spring, Summer. 2 credits—CBI only. 237 and MTH 113.*

Extension of 237 involving calculus concepts. 237 plus 284 equals 287. Kinematics, dynamics, rigid body motions, energy, and oscillatory motion.

### 285. *Calculus Concepts in Physics II*

*Fall, Winter, Spring, Summer. 2 credits—CBI only. 238, 284, and MTH 214.*

Extension of 238 involving calculus concepts. 238 plus 285 equals 288. Electrostatic interactions, magnetic fields: forces and sources, magnetostatics, and electrical circuits.

### 286. *Calculus Concepts in Physics III*

*Fall, Winter, Spring, Summer. 2 credits—CBI only. 239, 285 and MTH 214.*

Extension of 239 involving calculus concepts. 239 plus 286 equals 289. Wave Phenomena, photons, atomic states and transitions, quantum mechanics, subatomic phenomena.

### 287. *Principles of Physics*

*Fall, Winter, Spring. 4(5-0) MTH 113.*

Mechanics.

### 287A. *Physics IA*

*(281A.) Fall, Winter, Spring. 1 credit —CBI only. MTH 113; PHY 281 or concurrently.*

Extensions of 281, plus topics from: frames of reference, special relativity, rocket equation, forced oscillations, resonances, fluid motion, numerical (computer) solutions, moments of inertia, gyroscopic motion.

### 288. *Principles of Physics*

*Winter, Spring. 4(5-0) 287; MTH 214 or approval of department.*

Heat and thermodynamics, electricity and magnetism.

### 288A. *Physics IIA*

*(282A.) Fall, Winter, Spring. 1 credit —CBI only. 282 or concurrently, MTH 214 or approval of department.*

Extensions of topics from 282, plus topics from: entropy, transport phenomena, general relativity, electrons, atoms, molecules, solids, electromagnetic fields, energy, alternating currents, numerical (computer) solutions.

### 289. *Principles of Physics*

*Fall, Spring, Summer. 4(5-0) 288; MTH 214 or approval of department.*

Wave motion, sound, light, and modern developments.

### 289A. *Physics IIIA*

*(283A.) Fall, Winter, Spring. 1 credit —CBI only. 283 or concurrently, MTH 214 or approval of department.*

Extensions of the 283 material plus topics from: spectral orgins and analysis, optics, standing wave phenomena, diffraction, quantum mechanics, numerical (computer) solutions, radioactivity, elementary particles.

### 291. *Physics I*

*Spring. 4(5-0) MTH 214 or concurrently. Honors section recommended.*

First of a five-term course sequence in elementary physics consisting of 291, 292, 293, 294 and 395. In this sequence the principles of physics are presented in a unified manner that emphasizes modern concepts. Mechanics, including special relativity.

### 291A. *Honors Physics IA*

*Fall, Winter, Spring. 1 credit—CBI only. 287A, MTH 113.*

Subjects and topics as in 281 and 287A, generally on a more advanced level.

### 291B. *Honors Physics IB*

*Fall, Winter, Spring. 5 credits—CBI only. MTH 113.*

Combined material of 281 plus 287A plus 291A are taken in one term.

### 292. *Physics II*

*Fall. 4(5-0) 291; MTH 215 or concurrently.*

Continuation of 291. Electricity and magnetism with some special relativity.

### 292A. *Honors Physics IIA*

*Fall, Winter, Spring. 1 credit—CBI only. 288A, MTH 214.*

Subjects and topics as in 282 and 288A, generally on a more advanced level.

### 292B. *Honors Physics IIB*

*Fall, Winter, Spring. 5 credits—CBI only. 291B, MTH 214.*

Combined material of 282 plus 288A plus 292A is covered in one term.

### 293. *Physics III*

*Winter. 4(5-0) 292.*

Continuation of 292. Wave physics including optics.

### 293A. *Honors Physics IIIA*

*Fall, Winter, Spring. 1 credit—CBI only. 289A, MTH 215.*

Subjects and topics as in 283 and 289A, generally on a more advanced level.

### 293B. *Honors Physics IIIB*

*Fall, Winter, Spring. 5 credits—CBI only. 292B, MTH 215.*

Combined material of 283 plus 298A plus 293A is covered in one term.

### 294. *Physics IV*

*Spring. 4(5-0) 293 or 289.*

Continuation of 293. Introduction to quantum physics.

### 297. *Principles of Physics Laboratory*

*Fall, Winter. 1(0-2) 281 or concurrently.*

Mechanics.

### 298. *Principles of Physics Laboratory*

*Winter, Spring. 1(0-2) 282 or concurrently.*

Heat and thermodynamics, electricity and magnetism.

### 299. *Principles of Physics Laboratory*

*Fall, Spring. 1(0-2) 283 or concurrently.*

Wave motion, sound, light and modern developments.

### 301. *Bohr and Einstein: The Concept of Nature in Our Day*

*Fall. 3(3-0) Juniors.*

Basic contemporary ideas about the natural world and their significance for man presented through study of the lives of Niels Bohr (quantum theory) and Albert Einstein (relativity theory).

### 304. *Special Problems*

*Fall, Winter, Spring, Summer. 1 to 5 credits. May re-enroll for a maximum of 5 credits. Approval of department.*

### 310. *Calculus Concepts in Physics*

*Fall, Winter, Spring, Summer. 5(5-0) 237, 238, 239; MTH 214.*

A transition course to prepare students who had non-calculus introductory physics for upperdivision courses. Discussions and problems in mechanics, electricity and magnetism, wave motion and modern physics. Familiarity with non-calculus introductory physics is assumed.

### 357. *Topics in Contemporary Physics*

*Spring. 4(4-0) One year of general college physics.*

Atomic and nuclear physics, cosmic rays and elementary particles, nuclear energy, new theoretical concepts. Recommended for prospective high school teachers.

### 364. Introduction to Modern Physics I

*Fall, Winter, Spring. 3(3-0) 289, MTH 215.*

Atomic structure; wave and particle aspects of radiant energy; optical and X-ray spectra.

### 365. Introduction to Modern Physics II

*Winter, Spring. 3(3-0) 364 or 294.*

Nuclear, molecular, solid state and elementary particle physics. Special emphasis is given to applications such as reactors, super conductors, semi-conductors, fusion reactions, particle accelerations, etc.

### 368. Elementary Solid State Physics I

*Winter. 3(3-0) 364 or 294.*

Crystal structure and binding; lattice dynamics, specific heat, thermal conductivity; free electron theory of metals, conductivity, optical properties; elementary band theory; Hall effect, effective masses in metals and semi-conductors.

### 369. Elementary Solid State Physics II

*Spring. 3(3-0) 368.*

Ferroelectricity, paramagnetism, ferromagnetism, antiferromagnetism, domain walls; point defects, and dislocations in metals, formation and motion energies, internal friction, radiation damage.

### 395. Physics V

*Fall. 3(3-0) 293B, or 294, or 364.*

Continuation of 294. Thermodynamics and statistical physics.

### 400H. Honors Work

*Fall, Winter, Spring. Variable credit.*

### 404. Special Problems

*Fall, Winter, Spring, Summer. 1 to 5 credits. 289 or 293; approval of department.*

### 419. Physical Phenomena and Electronic Instrumentation I

*Winter. 4(3-3) 289, MTH 215. Interdepartmental with Electrical Engineering.*

Concepts of electronics relative to uses in investigations of physical phenomena and their subsequent applications to provide reliable instrumentation. Nuclear radiation detectors, photometers and magnetometers are examples of specific topics covered.

### 420. Physical Phenomena and Electronics Instrumentation II

*Spring. 3(2-3) 419.*

Noise and its characterization. Typical electronics instruments are analyzed in detail. A reliable instrument that uses a physical effect is developed by the student.

### 427. Intermediate Mechanics

*Fall. 3(3-0) 289; MTH 310 or concurrently.*

Statics and dynamics of a particle and of rigid bodies; linear and non-linear oscillations; gravitation from a field point of view; transformation properties of physical quantities; introduction to mathematical techniques of theoretical physics.

### 428. Intermediate Mechanics

*Winter. 3(3-0) 427.*

Continuation of 427.

### 429. Advanced Mechanics

*Spring. 3(3-0) 428.*

Advanced methods of theoretical mechanics; generalized coordinates; Lagrange's and Hamilton's equations; the wave equation, theory of vibrations.

### 430. Introduction to Radioactivity and Radioisotope Techniques

*Spring, Summer. 2(3-0) or 3(3-0) One year each of general college chemistry and physics. Interdepartmental with the Department of Chemistry.*

*First 7 weeks.* Elementary nuclear processes and properties with emphasis on radioactivity, its measurement, and its interaction with matter. Effects of radiation on chemical and biological systems. Applications of nuclear technology, safety and environmental factors. *Last 3 weeks.* Fundamentals of nuclear models, reactions and decay mechanisms. Basic principles of nuclear reactors and accelerators.

### 431. Laboratory for Radioactivity and Radioisotope Techniques

*Spring, Summer. 1(0-3) CEM 161, 430 concurrently. CEM 162 recommended. Interdepartmental with the Department of Chemistry.*

Introduction to nuclear instrumentation. Experimental techniques for application of radioisotopes to problems in chemistry, the life sciences, and industry.

### 438. Geometrical Optics

*Fall. 4(3-3) 289, MTH 215.*

Geometrical optics including Fermat's Principle, reflection, refraction, mirrors, thin lenses, thick lenses, aberrations, and the effects of apertures and stops.

### 439. Physical Optics

*Winter. 4(3-3) 289, MTH 215.*

Physical optics including Huygens-Fresnel Principles, interference, diffraction, and coherence. Additional topics will be selected from Fourier transforms of wave forms, convolution, diffraction and image formation, spatial filtering, holography and polarization.

### 447. Electricity and Magnetism I

*Winter. 4(4-0) 18 credits in physics 281 and above.*

Advanced study of electromagnetic phenomena; electrostatic potentials from Laplace's and Poisson's equations; effects of dielectric and magnetic materials; magnetic fields and potentials; induced e.m.f.; Maxwell's equations; electromagnetic radiation and waves.

### 448. Electricity and Magnetism II

*Spring. 4(4-0) 447.*

Continuation of 447.

### 457G. Advanced Physics Laboratory (General)

*Fall. 3(1-6) 15 credits in physics 281 and above.*

Experiments in modern physics of historical interest and in general physics research techniques. Emphasizes experimental methods and proper treatment of data. Independent work encouraged.

### 457N. Advanced Physics Laboratory (Nuclear)

*Winter of even-numbered years. Spring of odd-numbered years. 3(1-6) 15 credits in physics 281 and above.*

Experiments in nuclear physics. Detection of nuclear radiation and determination of nuclear properties. Emphasizes research methods and proper treatment and interpretation of data. Independent work encouraged.

### 457S. Advanced Physics Laboratory (Solid State)

*Spring of even-numbered years, Winter of odd-numbered years. 3(1-6) 15 credits in physics 281 and above.*

Experiments in low temperature and solid state physics. Emphasizes research methods and proper treatment and interpretation of data. Independent work encouraged.

### 491. Introduction to Quantum Mechanics I

*Fall. 3(3-0) 294 or 364; MTH 310 or concurrently.*

Schroedinger wave equation and its applications; angular momentum; one electron atoms; moments and spin; perturbation methods; absorption and emission of radiation; atomic and molecular structure.

### 492. Introduction to Quantum Mechanics II

*Winter. 3(3-0) 491.*

Continuation of 491.

### 493. Introduction to Quantum Mechanics III

*Spring. 3(3-0) 492.*

Continuation of 492.

### 497. Introduction to Elementary Particle Physics

*Fall. 3(3-0) 294 or 364 or 491.*

Relativistic kinematics, invariance principles. Phenomenological analysis of elementary particle interactions with matter. Weak, electromagnetic and strong interactions. High energy accelerators and techniques in experimental high energy physics.

### 498. Introduction to Nuclear Physics

*Spring. 3(3-0) 294 or 364 or 491.*

Interactions of nuclear radiations with matter; properties of nuclei; alpha, beta, gramma decay; nuclear models; nuclear reactions and elementary applications of scattering theory; reactors, accelerators; introduction to high-energy physics.

### 800. Research Methods

*Fall, Winter, Spring, Summer. 2(0-6) May re-enroll for a maximum of 6 credits. Beginning graduate students. Interdepartmental with the Department of Astronomy and Astrophysics.*

Problems and techniques of current research by taking part in the design and setup of experiments, data taking and reduction; study and practice of theoretical methods. Areas of study: solid state and molecular structure, nuclear, elementary particles, astronomy, astrophysics.

### 817. Techniques of Theoretical Physics

*Fall. 3(3-0) Graduate students; or approval of department.*

Application of contour integration to physical problems; basic concepts in theoretical formulation of quantum mechanical systems; solution of physical problem using Green's Functions, the delta function, series, integral transforms.

### 827. Theoretical Physics I

*Summer of odd-numbered years. 3(3-0) 428 or approval of department.*

Vector analysis, mechanics of a particle and of systems of particles. Lagrange's equations, Hamiltonian methods, rotational motion.

### 828. Theoretical Physics II

*Summer of even-numbered years. 3(3-0) 448 or approval of department.*

Special relativity, Maxwell's equations, electrodynamics and electromagnetic waves.

### 829. *Thermal and Statistical Physics*
*Winter. 3(3-0) Approval of department.*

Principles of thermodynamics; topics in kinetic theory; introduction to statistical mechanics.

### 837. *Quantum Mechanics I*
*Fall. 3(3-0) 428, 491.*

The formulation of quantum mechanics, superposition principle, state vector and representations; uncertainty principle; Schroedinger equation and its solution for physical systems.

### 838. *Quantum Mechanics II*
*Winter. 3(3-0) 837.*

Approximation methods, perturbation theory, applications to atomic transitions, angular momentum.

### 839. *Quantum Mechanics III*
*Spring. 3(3-0) 838.*

Collision processes and scattering theory, applications; many-particle systems.

### 840. *Symmetry in Solid State Physics*
*Spring. 3(3-0) Graduates or approval of department.*

Translational symmetry and Bloch's Theorem, reciprocal lattice, Brillouin zones; point groups, representations, character tables, molecular vibrations, group of the wave vectors and band theory of solids, crystal fields.

### 847. *Electromagnetic Theory I*
*Fall. 3(3-0) 428, 448.*

Electrostatics; Laplace's equation, Poisson's equation; Green's theorem; solution of problems by method of images; inversion; boundary-value problems in Cartesian, spherical and cylindrical coordinates; spherical harmonics; Bessel functions.

### 848. *Electromagnetic Theory II*
*Winter. 3(3-0) 847.*

Multipoles and multipole expansions; electrostatics of macroscopic materials, dielectrics, magnetostatics, vector potential, magnetic moments, Maxwell's equations for time-varying fields, energy and momentum conservation. Plane electromagnetic waves and polarization.

### 849. *Electromagnetic Theory III*
*Spring. 3(3-0) 848.*

Wave guides and resonant cavities, boundary-value problems. Simple radiating systems, antennas. Special relativity, covariance of electrodynamics, transformation of electromagnetic fields. Radiation by moving charges, Lienard-Wiechert potentials.

### 850. *Ionized Gases*
*Spring. 3(3-0) E E 835 or PHY 448. Interdepartmental with the Department of Astronomy and Astrophysics and Electrical Engineering and administered by Electrical Engineering.*

Elastic collision processes; Boltzmann equation; moment equations; basic plasma phenomena; motion of a charged particle in electrical and magnetic field; individual and collective charged particle behavior.

### 857. *Theoretical Mechanics I*
*Winter. 3(3-0)*

Two-body central force problems, rigid body motion, small oscillations, Hamilton's principle, Lagrangian and Hamiltonian formalism for particles and fields, canonical transformations, relativity.

### 858. *Theoretical Mechanics II*
*Spring. 3(3-0) Approval of department.*

Hamiltonian formalism for particles and fields, variational methods, canonical transformations, small oscillators, classical fields, relativity.

### 860. *General Relativity and Cosmology I*
*Fall of even-numbered years. 3(3-0) 858 or approval of department. Interdepartmental with the Department of Astronomy and Astrophysics.*

Conceptual foundations of general relativity theory; elements of tensor calculus; Riemann-Christoffel curvature tensor; the field equations; experimental tests; special solutions; the extension to cosmology.

### 861. *General Relativity and Cosmology II*
*Winter of odd-numbered years. 3(3-0) AST 860. Interdepartmental with the Department of Astronomy and Astrophysics.*

Relativistic cosmology: the model universes; steady-state theory; observational evidence and possibilities for decision among models; current problems.

### 867. *Quantum Mechanics IV*
*Fall. 3(3-0) 839.*

Transformation theory and invariance principles; the rotation group and theory of angular momentum; Wigner-Eckart theorem and applications.

### 868. *Relativistic Quantum Mechanics*
*Winter. 3(3-0) 867.*

Relativistic equations of motion; Dirac equation, free particle solutions and Lorentz transformation properties; interaction with electromagnetic fields; quantization of scalar, electromagnetic and Dirac fields.

### 869. *Quantized Fields*
*Spring. 3(3-0) 868.*

Heisenberg representation, S-matrix reduction formulae, Feynman rules, quantum electrodynamics; topics from many-body theory.

### 877. *Statistical Mechanics I*
*Fall. 3(3-0) Approval of department.*

Necessity of statistical considerations, ensembles, probability distributions and density matrices, Liouville's equation, equilibrium distributions, microscopic basis of thermodynamics; applications to thermodynamics of spin systems.

### 878. *Statistical Mechanics II*
*Winter. 3(3-0) 877.*

Applications to thermodynamic properties of ideal classical and quantum gases, and to imperfect gases and interacting spin systems. Nonequilibrium distributions and transport theory, the Boltzmann equation, Kubo's linear response theory, Onsager's relations.

### 879. *Statistical Mechanics III*
*Spring. 3(3-0) 878.*

Special topics chosen at discretion of instructor. Topics may include phase transitions, critical phenomena and renormalization group techniques; Green's function and diagrammatic techniques for interacting systems.

### 899. *Research*
***Fall, Winter, Spring, Summer. Variable credit. Approval of department.***

### 927. *Elementary Particle Physics*
*Fall. 3(3-0) 869.*

Properties of elementary particles; invariance principles and conservation laws; strong, electromagnetic, and weak interactions; pion physics.

### 928. *Elementary Particle Physics*
*Winter. 3(3-0) 927.*

Baryon and meson resonances, unitary symmetry, dispersion relations.

### 929. *Elementary Particle Physics*
*Spring. 3(3-0) 928.*

Selected current topics, partial wave amplitudes and Regge poles; current algebra and weak interactions.

### 937. *Molecular Structure and Spectra I*
*Fall of odd-numbered years. 3(3-0) 837 or concurrently.*

Structure and spectra of diatomic molecules.

### 938. *Molecular Structure and Spectra II*
*Winter of even-numbered years. 3(3-0) 937.*

Structure and spectra of polyatomic molecules.

### 939. *Molecular Structure and Spectra III*
*Spring of even-numbered years. 3(3-0) 938.*

Advanced topics in vibration-rotation theory of polyatomic molecules.

### 947. *Solid State Physics I*
*Fall. 3(3-0) 839 and 840.*

Crystal symmetry, crystal binding, lattice vibrations and specific heat, one-electron theory; Hartee-Fock equation, Brillouin zones.

### 948. *Solid State Physics II*
*Winter. 3(3-0) 947.*

Effective mass approximation. Exchange and correlation corrections. Theory of conductivity and related effect, metals and semiconductors.

### 949. *Solid State Physics III*
*Spring. 3(3-0) 948.*

Ionic crystals. Imperfections in crystals, plastic deformations, color centers. Optical properties. Rectification, transistors, selected topics.

### 957. *Nuclear Physics I*
*Fall. 3(3-0) 867.*

Nucleon-nucleon scattering, nuclear sizes and shapes, multipole moments; shell model; collective states.

### 958. *Nuclear Physics II*
*Winter. 3(3-0) 957.*

Experimental methods and instrumentation; nuclear reactions; inelastic scattering and particle transfer.

### 959. *Nuclear Physics III*
*Spring. 3(3-0) 958.*

Many-body methods in nuclear physics; Bethe-Goldstone equation; effective interaction; nuclear models.

### 984. *Advanced Readings in Physics or Astronomy*
*Fall, Winter, Spring, Summer. Variable credit. Interdepartmental with the Department of Astronomy and Astrophysics.*

### 987. *Advanced Topics in Physics*

*Fall, Winter, Spring. 3(3-0) or 4(4-0)*

In any one term this course will be devoted to a single topic, such as advanced quantum theory, quantum electrodynamics, specialized topics in solid state physics, statistical mechanics, relativity theory and cosmology.

### 989. *Waves and Radiations in Plasmas*

*Fall of even-numbered years. 3(3-0) 850. Interdepartmental with the Department of Astronomy and Astrophysics and Electrical Engineering. Administered by Electrical Engineering.*

Plasma oscillation; interaction, electromagnetic fields with plasmas, wave propagation in magnetionic media; plasma sheath; radiation of electric source in incompressive and compressive plasmas; electroacoustic waves; magnetohydrodynamics; research topics in plasmas.

### 999. *Research*

*Fall, Winter, Spring, Summer. Variable credit. Approval of department.*

## PHYSIOLOGY PSL

## College of Human Medicine
## College of Natural Science
## College of Osteopathic Medicine
## College of Veterinary Medicine

### 240. *Introductory Physiology*

*Fall, Spring, Summer. 4(3-2) Sophomores or approval of department.*

Survey of the physiology of circulatory system, excretion, nervous system and special senses, digestion, metabolism and endocrinology.

### 241. *Introductory Physiology*

*Winter, Summer. 4(3-2) 240.*

Continuation of 240. Physiology of muscle function and neuro-muscular relationships; exercise; respiration; changes in organ systems in relation to muscular exercise.

### 323. *Physiology, Anatomy, and Hygiene of the Eye*

*Fall. Summer of even-numbered years. 3(2-2) 240; Elementary Education or Special Education major, or approval of department.*

Basic course in anatomy, physiology, and hygiene of the visual system; includes discussion of normal visual functioning and abnormal visual functioning, with methods of correction and education implications.

### 331. *Human Physiology*

*Winter. 4(4-0) ANT 316; CEM 132, or approval of department.*

### 332. *Human Physiology*

*Spring. 4(4-0) 331.*

### 401. *Comparative Physiology I*

*Fall. 4(3-4) 240 or B S 212 and CEM 132. Interdepartmental with the Department of Zoology.*

A comparison of osmoregulation, digestion, respiration, and other physiological processes in a wide range of organisms.

### 402. *Comparative Physiology II*

*Winter. 4(4-0) 401 or approval of department. Interdepartmental with and administered by the Department of Zoology.*

A comparison of sensory, motor, endocrine and other integrative mechanisms in animals.

### 416. *Physiology of the Cell*

*Fall. 3(3-0) BCH 401 or 451.*

Physiologic mechanisms common to all living cells with emphasis on those of the vertebrates. The functions of the cell membrane and cytoplasm are studied as the basis for the physiologic behavior of vertebrate organs and systems.

### 417. *Physiology of the Cell*

*Summer. 4(3-3) 4(6-6) 5 weeks. This is equivalent to 3 hours of lecture and 3 hours of laboratory on a ten-week basis. Approval of department.*

Physiologic mechanisms common to all living cells with emphasis on those of the vertebrates. The functions of the cell membrane and cytoplasm are studied as the basis for the physiologic behavior of vertebrate organs and systems.

### 440. *Avian Physiology*

*Spring. 4(3-3) Approval of department. Interdepartmental and administered jointly with the Department of Poultry Science.*

A survey of the systemic physiology of birds emphasizing digestion, metabolism, the endocrines, and reproduction.

### 444. *Mammary Physiology*

*Winter. 4(3-2) 240, BCH 200. Interdepartmental and administered jointly with the Department of Dairy Science.*

Anatomy of mammary gland. Hormonal and nervous control of mammary growth, initiation and maintenance of lactation. Biochemistry of milk secretion. Physiology of milking; physiological, pathological and management factors affecting lactation.

### 445. *Endocrinology and Reproduction of Farm Animals*

*Fall. 4(5-0) 240. Interdepartmental and administered jointly with the Department of Dairy Science.*

Endocrine and reproductive systems are presented with emphasis upon characteristics which can be altered for economic benefit and upon causes, prevention, and treatment of endocrine abnormalities.

### IDC. *Biological Membranes*

*For course description, see* Interdisciplinary Courses.

### 480. *Special Problems*

*Fall, Winter, Spring, Summer. 1 to 5 credits. Approval of department.*

### 497. *Principles of Endocrinology*

*Winter. 4(4-0) One year organic chemistry; ZOL 317. Interdepartmental with and administered by the Department of Zoology.*

Hormonal principles, illustrated by experimental observations, in vertebrates and invertebrates. Emphasis on cellular endocrinology. Group discussion, background in organic chemistry and cell biology strongly recommended. Term paper required.

### 500A. *Introductory Physiology for Medicine*

*(500.) Fall, Winter. 5(5-0) Admission to the professional program in a college of medicine.*

Concepts and problems in physiology to be followed by supplemental physiology instruction during subsequent phases of medical training.

### 500B. *Introductory Physiology for Medicine*

*Summer. 3(3-0) or 4(3-1) Admission to the professional program in a college of medicine.*

Classical concepts and problems in physiology which form a base for clinical physiology training in subsequent terms.

### 500C. *Introductory Physiology for Medicine*

*Fall. 3(3-0) or 4(3-1) Admission to the professional program in a college of medicine.*

Continuation of 500B.

### 801. *Advanced Physiology*

*(501.) Winter. 4(3-2) 332 or 402 or approval of department; courses in anatomy, histology, biochemistry and calculus recommended.*

Principles of physiological control systems. Physiology of the nervous system including, neuromuscular, reflex, sensory and autonomic nervous function. Physiology of respiration; acid-base, regulation of body fluids.

### 802. *Advanced Physiology*

*(502.) Spring. 4(3-2) 332 or 402 or approval of department; courses in anatomy, histology, biochemistry and calculus recommended.*

Physiology of kidney and micturition, blood and cardiovascular system.

### 803. *Advanced Physiology*

*Fall. 4(3-2) 332 or 402 or approval of department; courses in anatomy, histology, biochemistry and calculus recommended.*

Physiology of the digestive system, regulation of metabolism; endocrinology and reproduction.

### 808. *Neuroendocrinology*

*Winter. 3(3-0) Approval of department.*

Anatomical, biochemical and physiological aspects of neuroendocrinology. Control systems and interaction among endocrine glands will be emphasized.

### 819. *Kidney Physiology and Electrolyte Metabolism*

*Summer. 3(3-0) 802, approval of department.*

Critical study of the literature on classical and contemporary prinicples of renal physiology and related aspects of body fluid and electrolyte metabolism.

### 835. *Neurophysiology*

*Winter of odd-numbered years. 4(2-4) Approval of department.*

Functions and properties of the peripheral and central nervous systems.

### 836. *Physical Principles of Biological Systems*

*Winter. 3(3-0)*

Application of laws and methods of physics to measurement and description of physiological phenomena.

### 837. *Radiobiology*

*Fall. 3(3-0) Approval of department.*

Application of radioactive tracer techniques to study of biological functions. Determination of turnover rates and tissue constituents by isotope dilution. Control of radiation hazards.